Changes in Monetary and Exchange Rate Regimes and the Transmission Mechanism of Monetary Policy in Israel, 1989.IV – 2002.I

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I. Introduction

The objective of the present research is the evaluation of the changes in the monetary and in the exchange rate policies in Israel during the last twelve years (1990-2002) in the context of a quarterly econometric model of the Israeli economy. We are interested in particular in the way these policy changes affected the evolution of economic activity and of inflation during the estimation period and in their contribution to changes in the different channels of the transmission mechanism of monetary policy to inflation.

The aforementioned policy changes refer to the gradual transition of the Israeli economy from a fixed exchange rate regime, immediately after the stabilization plan in July 1985, to a managed exchange rate, within an initially horizontal exchange rate band and later on within a crawling exchange rate band (end of 1991), and eventually to a floating exchange rate (July 1997) within an ever widening exchange rate band, alongside the gradual abandoning of the exchange rate as the nominal anchor of the economy. These changes in the exchange rate regime were accompanied by the use of the interest rate by the BoI for the conduct of its monetary policy and the eventual introduction of inflation targets.

There exists an interdependence among these regime changes. The increasing flexibility of the exchange rate regime which arose initially from the need to prevent speculative attacks on the foreign currency reserves of the BoI gave way to the transition to a free float reflecting the authorities will to liberalize capital flows which would have constituted a threat for the stability of a managed exchange rate regime. The gradual transition to a floating exchange rate system facilitated the use of the BoI interest rate on liquid commercial bank assets (liabilities) for the conduct of its monetary policy, while the rising will to liberalize capital flows found also support in the decreasing needs of the government to finance its budget deficit which was drastically reduced following the stabilization program of 1985.

The slope of the crawling exchange rate band, adopted at the end of 1991, was determined as the inflation differential between Israel and its main trading partners and allowed thereby the BoI to derive the domestic inflation rate which was consistent with the slope of the exchange rate band, given the inflation rate in the economies of Israel's main trading partners.

This domestic inflation rate has been often considered by many economists as an inflation target and the date of the transition to the crawling exchange rate band has been widely referred to as the date of the adoption of inflation targeting by the BoI. However it was only later, in 1994, that inflation targeting was officially adopted by the Israeli government and the BoI and that the interest rate at the discount window was explicitly used by the BoI as its main intermediate target substituting the nominal exchange rate.

The evaluation of the contribution of the aforementioned policy changes to the evolution of economic activity and of inflation is based on two distinct exercises. The first exercise consists of tracing the evolution of the economy by performing dynamic forecasts under the different policy regimes over a given time period assuming that these regimes remain unaltered during this period. This exercise allows us to compare inflation-output-gap pairs at given dates under different policy regimes. In the second exercise we examine the change in the impulse response functions of inflation and of economic activity brought about by the aforementioned policy changes.

The change in the relative importance of the different channels of the transmission mechanism of monetary policy as a result of monetary and exchange rate policy changes is based on an evaluation of the changes in the relative weight of these channels over time in the determination of inflation and of economic activity.

Our model does not contain a detailed specification and estimation of the real sector, unlike previous empirical work on the Israeli economy (Beenstock et al. (1994), Drachman and Zilberfarb (1987), Condor (1983), Artstein et al (1982), Cukierman et al.(1977), Evans

(1970)) limiting the analysis of the real sector to the extent necessary for allowing the differentiation among the various transmission channels of monetary policy. We have in common however concepts developed in these papers as well as in other empirical works on the Israeli economy[1].

Other empirical works, similar in their objectives to ours, have been undertaken in other countries including Great Britain (see Haldane (1995), Bank of England (1999)), Spain (Andres et al. (1997)) and Canada (Duguay (1994))[2] to mention only a few out of a much longer list of empirical work.

From the viewpoint of its objectives and its time horizon (short -medium term) our paper has affinities with the quarterly small macroeconomic model of the Israeli economy estimated by Azoulai and Elkayam (1999) and Elkayam (2001), which contrary Djivre and Ribon (2001) and to the present paper do not use direct measures of economic activity in their estimation but resort to its reduced form estimation.

In this paper the BoI short term nominal interest rate serves as a measure of the monetary policy stance and it is estimated in the context of a reaction function à la Taylor (1993). We refrain however from refering to the estimated equation of the interest rate as a central bank's reaction function, and we consider it rather as a parsimonious description of the factors affecting the short-run nominal interest rate. This is mainly because of the problem of the observational equivalence (see Christiano et al. (1998), and Minford et al. (2001)).

Our estimation results point out that monetary policy affects inflation through various channels in the following order. Changes in the interest rate affect first inflation

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[1] See for instance recent research on the estimation of the Phillips curve Lavi and Sussman (1997), Bufman and Leiderman (1995). See also Fiorella del Fiore(1998) on the transmission of Monetary Policy in Israel since 1990, who has followed a different methodology (Romer-Romer Dates). Aviran (1998) estimated the effect of monetary policy on inflation and on economic activity through independent equation estimation and not through an integrated model allowing for the calculation of dynamic multipliers.

[2] For empirical work on components of our model and especially on the Phillips curve see Fuhrer (1995), King and Watson (1994). For a survey see a collection of papers in "Monetary Policy and the Inflationary Process", B.I.S, 1997.

through their effect on the nominal exchange rate, as it has been found in Ball (1999). This channel is characteristic of small and open economies like Israel (Djivre and Ribon (2003)). Only at a later stage, do the real interest and exchange rate changes affect economic activity and through it inflation in the context of the typical channel of monetary policy transmission characterizing large and rather closed economies (Mankiw (2000) and Vinals & valles (1999)).

The estimation results enable us to differentiate between three different monetary policy regimes. The first one began in 1990 and ended with the adoption of inflation targeting in 1994, the second one began in 1994 and ended with the transition to a pure float in 1997 and the third one began in 1997, when monetary policy was tightened further according to the estimation results, and was still relevant at the end of the sample period (2002.1). With respect to changes in the exchange rate regime our model identifies two different periods - the first one prior to and the second one following the transition of Israel to an essentially pure float as of July 1997.

The estimation results indicate also that when the long-run relationship among wages, prices and productivity is perturbed the adjustment is made by nominal wages, prices and productivity remaining exogenous to this process.

The outcome of a dynamic simulation within the sample indicates a satisfactory goodness of fit excluding labor productivity and wage inflation who perform rather poorly and indicate that an alternative way of estimation of labor productivity may be necessary.

Our paper consists of four additional parts. In the second part we present an overview of our econometric model, the estimated equations and the estimation results. In the third part we examine the dynamic properties of the estimated model which include dynamic forecasting and the Impulse response functions obtained in reaction to different structural shocks. In the fourth part we examine the effect of the policy regime changes on the evolution of economic activity and inflation and on the relative importance of the different transmission mechanism channels of monetary policy.

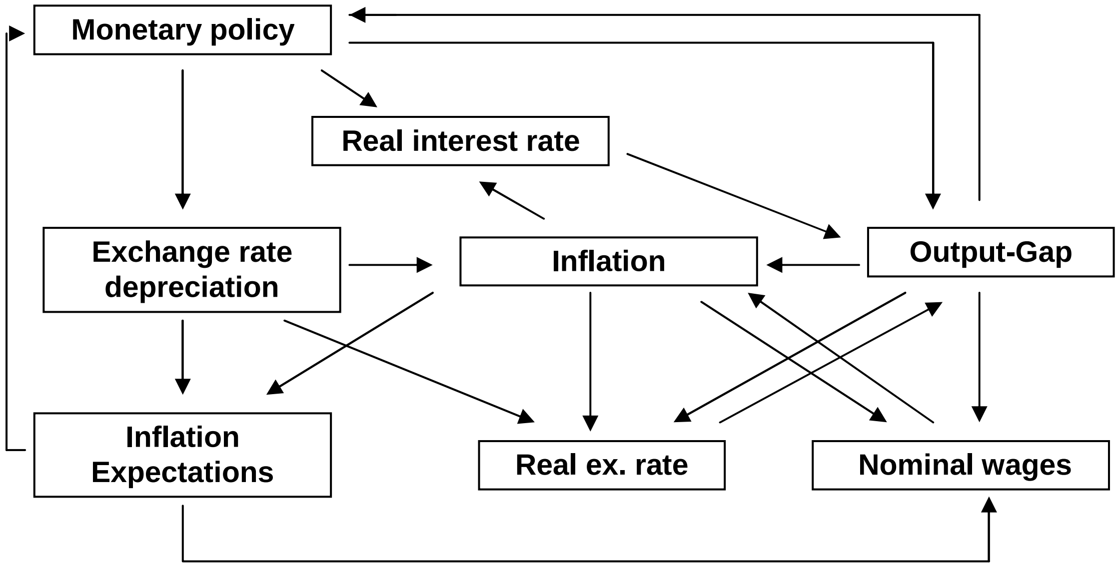
II. The Model

a. An Overview

Our model is a broad IS model of a small and open economy in which domestic product is demand determined and it is estimated on the basis of quarterly data for the period between 1989.4 and 2002.1 using the three stage least squares procedure. In this model monetary policy affects real activity in the short run through its effect on the real exchange rate and on the short term ex-post real interest rate and inflation through its direct effect on the nominal exchange rate and its indirect effect on inflation expectations and price and wage setting.

The transmission mechanism of monetary policy described by our model may be diagrammatically represented as follows:

Diagram 1: The transmission mechanism of Monetary policy



Our model consists of ten regression equations describing the evolution of economic activity and of inflation estimated simultaneously using the 3SLS procedure and a labor productivity equation estimated using the 2sls procedure. In the regression estimation we differentiate between short-run and long-run relationships, using cointegration and error-correction methodologies.

The regression equations of our model may be differentiated into four categories. Equations describing the evolution of real sector variables, equations describing the evolution of variables in the nominal sector, equations describing the evolution of interest rates – real and nominal- and identities which allow the determination of variables serving as regressors in the estimated equations. The real-sector equations include a regression for the output-gap, for the depreciation of the real exchange rate and for changes in labor productivity. The regressions for inflation include three inflation equations, inflation expectations, and nominal wages[3]. The interest rate equations include the cost of liquid funds supplied to the commercial banking sector, which is determined by the BoI in the context of a reaction function, and the cost of loanable funds to the business sector and consumers which in its turn is based on the central bank key-interest rate.

The identities allow the determination of variables serving as regressors in the estimated equations. In this way the nominal exchange rate path, which constitutes one of the components of domestic prices, may be derived from the evolution of the estimated real exchange rate and from that of the domestic product prices. In a similar way the estimated nominal wage equation (rates of change) and the estimated nominal interest rate determine together with the estimated inflation rate the evolution of real wages and of short run real ex-post interest rates which affect both inflation and economic activity.

b1. The nominal sector of the economy.

[3] In the first equation we estimate quarterly inflation in terms of the business sector gdp deflator. In the second equation we estimate the quarterly inflation of the gdp deflator and in the third equation we estimate the cp inflation rate.

The price formation process assumed in our model is based on a two stage production process whereby firms produce domestic product (GDP) using capital and labor and in the second stage this domestic product is used together with imported materials to produce output. The business sector price dynamics are determined in the first stage of this production process while the consumer price dynamics are determined in the second stage.

With respect to the determination of business sector prices and inflation we have assumed here that there exist two types of firms. Exporting firms producing tradable goods whose prices are determined in the international market and firms producing for the local market. The latter are of two types: forward looking firms and backward looking firms. Forward looking firms adjust their prices according to the expected inflation rate, which is also estimated within our model, while backward looking firms adjust their prices according to past changes in their unit labor costs. As a result business sector product price inflation may be formulated as a function of expected inflation, of past changes in unit labor costs and of the depreciation of the nominal exchange rate. We have also assumed that firms take into consideration when adjusting their prices the level of economic activity and in particular its deviation from its full-capacity level (i.e the output-gap)

The assumption of the two-stage price formation process implies that changes in the nominal exchange rate affect consumer price inflation both directly through the cost of imported materials and indirectly through its effect on the GDP prices.

The adjustment of nominal wages is made by workers in line with expected inflation, with the deviation of economic activity from its full-capacity level and with the deviation of their real wage from labor productivity.

b.2 The real-sector equations

The specification of the output-gap equation, the real exchange depreciation rate equations and the BoI interest rate derive from Djivre and Ribon (2000). The main difference between the latter and the present model with respect to these equations lies in the fact that the output gap equation has been modeled here as an IS equation in deviations from full-employment and not as a reduced-form equation of an AD-AS model and as a result it does not include wages. The IS specification is consistent with the price setting process described earlier since in the context of an AD-AS model, the price setting process cannot be assumed independently of the AD and AS equations as we have done here[4]. Moreover the interest rate equation estimated here allows for a regime change in monetary policy after 1997.

c. The Regression Equations

c.1 The output gap

The output-gap measures deviations of the business sector product from its full capacity level in log terms and the estimated equation has been specified as an IS function. The full capacity level of economic activity is obtained after we introduce into a separately estimated production function of the business sector the long run trend values for labor and capital[5].

The output gap, **gap,** is positive during downturns in economic activity and negative during upturns since it has been defined as the log difference between the potential and the actual product of the business sector

We have used as regressors variables referring both to domestic and to international demand. The factors affecting domestic demand include a moving average of the ex-post short term real interest rate, **rhhd**, and a moving average of the government budget deficit-gdp ratio, **pdefgdp**. The real interest rate should have appeared here in deviations from its

[4] See also Djivre and Ribon monetary planning for 2002-03.
[5] See Djivre and Ribon (2000).

long-run level. We have assumed, as a result, that this level has remained constant over the estimation period and is incorporated in the regression intercept.[6]

The variables measuring foreign demand for the home good include a moving average of the deviations, **tfpres1,** of the real exchange rate from its long-run value, a moving average of the deviations of the log of the volume of world trade, **log(wt)**, from its trend, which is calculated as an HP filter of quarterly data; and the deviations of tourist entries to Israel from the expansion of tourist services in the U.S.A, **log(tour_entry)-log(tour_us)**. This variable provides a proxy for the disruption in foreign demand caused by a deterioration in the domestic security conditions. The estimated regression includes also a lagged value of the dependent variable and an AR factor.

(1) gap = g(0) – g(1).MAtfpres1 + g(2).MA(rhhd)-g(3).MA(log(wt) – Lwt_hp)
– g(4).MA((log(tour_entry) – log(tour_us)) – g(5).MA(pdefgdp) + g(6).gap(-1) +
[g(7)=AR(1)]

The signs of the regressions coefficients are as specified above and the estimation results together with the exact specification of the regressors may be found in Appendix 2.

The estimated coefficients have the expected sign and the estimation results indicate that monetary policy affects economic activity through two distinct channels. The first one is the real exchange rate channel and the second one is the real interest rate channel.

The estimation results indicate also that while the lag with which monetary policy affects real activity is not very big, one to two quarters, its effect is rather prolonged and lasts for three quarters in either channels.

A Wald test performed on the estimated regression coefficients indicates that we cannot reject the hypothesis that the real interest rate coefficient and the coefficient of the lagged output-gap add-up to one. This finding implies that an increase in the real short term

[6] Gruen et al. (1999) use a similar assumption in estimating the NAIRU for Australia.

interest rate by one percentage point beyond its long run-level brings about, other things equal a commensurate rise in the output-gap.

c.2 The real exchange depreciation rate.

This equation has been specified in terms of the rate of depreciation, **dRER,** of the real exchange rate in the context of an error correction process. As real exchange rate (**RER**) we have defined the ratio of the price of exports in local currency to the gdp deflator. Short-term changes in the real exchange rate according to the present specification are brought about by the error correction process measured by the residual, tfpres1, of the long-run cointegration equation for the RER lagged by one quarter and by additional factors[7]. The economic reasoning behind the long-run cointegration equation is that a relative increase in the productivity in the tradable goods sector over time gives rise to a real exchange rate appreciation and vice versa[8].

The additional factors affecting the short run evolution of the real exchange rate include the lagged dependent variable, the output-gap which should be negatively correlated with the real exchange depreciation rate and the differential between the interest rate on domestic currency denominated liabilities, **ihhd**, and the interest rate on foreign currency liabilities, **Eurosal**. The latter is an interest rate which has been calculated on the basis of the interest rates on the currencies which make-up Israel's currency basket using as weights the corresponding currency weights.

Higher economic activity expressed in a lower value of the output-gap arising from either lower domestic or foreign demand is consistent with real exchange rate depreciation over time. A relatively higher interest rate on domestic currency denominated liabilities supports capital inflows leading thereby to a nominal and real exchange rate appreciation in the short run. We have allowed the transition to a floating exchange rate after 1997 to affect

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[7] See appendix 1.
[8] See Zusman(1998) and Djivre Ribon (2000).

the interest rate differential coefficient through the introduction of a dummy variable, $\mathbf{d_{973aft}}$, in the regression – slope- coefficient.

We have also included in the estimated equation the rate of change in export prices in dollar terms, **d(log(pgexp))**, has been allowed to decrease over time decreasing over time and a dummy variable, $\mathbf{d_{98q4}}$, accounting for the exchange rate crisis during the last quarter of 1998.

$$\textbf{(2)}\quad \mathbf{dRER = q(0) - q(1).dReR(-1) - q(2).tfpres1(-1) - q(3).(i_{hhd}\ -eurosal)}$$

$$\mathbf{-q(4).\ d_{973aft}\ (\ i_{hhd}\ -eurosal) + q(5).D(log(pgexp))*(1+1/log(T))}$$

$$\mathbf{+\ q(6).gap(-2) + q(7).d_{98q4}}$$

The estimation results together with the detailed definition of the regression variables appear in Appendix 2.

The rate of change of export prices, the short run negative effect of the interest rate differential on the real exchange depreciation rate and the dummy variable $\mathbf{d_{98q4}}$, whose coefficients were statistically significant, imply that the Israeli economy was characterized during the estimation period by nominal rigidities in the price determination process, which allowed changes in these variables to affect the short run evolution of the real exchange rate.[9] Indeed financial factors affecting interest rate differentials on domestic and foreign currency have been considered in empirical studies testing the PPP hypothesis as one of the main reasons for the deviations observed from parity in the short run because of nominal price stickiness [Rogoff (1996)].

This finding justifies also the specification of the gdp deflator inflation equation of the business sector (see discussion below) according to which the process of changing prices is

[9] The decreasing effect of export price changes reflects the liberalization in the goods market and the rising competition as a result of which a lower extent of rigidities should be observable.

partly backward looking and is as a result characterized by nominal rigidities in the short run.

The size of the interest rate differential coefficient prior to 1997 suggests that the widening of the interest rate differential by one percentage point led to a real exchange rate appreciation of a one quarter of a percentage point, implying that on an annual basis there existed a one to one relation between the interest rate differential and the exchange rate appreciation which increased later on. However this conclusion may provide an exaggerated estimate of this effect because the nominal exchange rate appreciation accompanying the change in the interest rate differential affects inflation reducing thereby the extent of the real exchange rate appreciation with the lapse of time.[10] From the estimation results it also transpires that the interest rate differential effect on the real exchange depreciation rate increased, as expected, by 0.10 percentage points following the transition to a pure float after July 1997.

c.3 The price equations

These equations are all in terms of rates of change and include the inflation rate in terms of the gdp deflator of the business sector, the inflation rate in terms of the gdp deflator, the inflation rate in terms of consumer prices and the equation for inflation expectations. The nominal exchange rate depreciation also belongs to this group of equations. It constitutes though an identity and not a regression equation since it is derived from the real exchange depreciation rate, the inflation rate in terms of the gdp deflator and the rate of increase in the dollar prices of foreign trade.

<u>The Business Sector price inflation.</u>

The business sector gdp price inflation, **dlpgdp_bs**, is the average quarterly inflation rate of the gdp prices in the business sector including start-up firms as of 1995. The distinction of

[10] Our specification does not account for the long-run capital flows and their short run-effect on the real exchange rate evolution and for the effect of the Investment-savings differential on the current acclount of the balance of paymrents

firms into exporting and producing for the local market, as discussed earlier, has allowed us to introduce the nominal exchange depreciation rate with respect to the U.S dollar, **dldol**, as a regressor in this equation together with variables which affect the pricing of firms producing for the domestic market. We have differentiated the latter into forward and backward looking firms. The forward looking firms base their pricing on inflation expectations while the backward looking firms use a mark-up pricing policy based on the past evolution of unit labor costs.[11]. The coefficients of these three variables in the estimated regression are expected to be positive and add up to unity, indicating that in the long run the inflation rate equation is homogeneous of degree one.

The unit labor costs have been defined in terms of the difference, **dw- dprod**, between the growth rate of nominal wages, **dw**, and changes in labor productivity, **dprod**, measured by the change in the gdp of the business sector per unit of labor input.

Inflation expectations, **exp,** are measured here by the twelve month-ahead expected inflation as the latter is derived by imposing a no arbitrage condition between returns on government indexed bonds and zero coupon nominal treasury bills (Makam) of the same maturity. The inflation expectations used here are in terms of consumer prices and not in terms of business sector gdp prices. The high correlation coefficient between gdp price inflation and expected cp inflation justifies, however, this contravention. In order to introduce only the forward-looking element of these inflation expectations as a regressor in the estimated equation, we substracted from the expected inflation rate the average inflation rate during the two previous quarters, **(dlpgdp_bs(-1)+ dlpgdp_bs(-2))/2.**

In addition the firms take into account in setting their prices, the deviation of economic activity from its full-employment potential measured here by the output-gap.

[11] The introduction of the change in export prices in dollar terms in the estimated regression did not give rise to a significant coefficient

Domestic product lower than its full-capacity level mitigates price increases and vice versa so that the coefficient of the output gap is expected to be negative.

The estimated regression does also include seasonal dummy variables and dummy variables accounting for the classification changes in the reporting of wages and of the business sector product as of 1995, $\mathbf{d_{951}}$, and for the exchange rate band realignment at the end of the first quarter of 1991.

We examined and found that the price level, nominal wages and labor productivity' measured by the product of the business sector per unit of labor input, are cointegrated, the coefficients of nominal wages and productivity being very close to unity as it would have been expected under perfect competition in the long run and introduced in the estimated equation an error correction component, **ECP**, indicating that firms tend to adjust their prices downwards when the price level is higher than the level of the unit labor costs[12].

$$\textbf{(3)}\quad \mathbf{dPgdp_{bs} = P_{(0)} + P_{(12)}.d_{9112} - P_{(10)}.d_{951} + P_{(11)}.Exp + P_{(2)}MA(dW\text{-}dprod)}$$

$$\mathbf{- P_{(3)}.(dPgdp_{bs}(-2) + dPgdp_{bs}(-1))/2 + P_{(4)}.MA(gap)}$$

$$\mathbf{+ P_{(5)}.dldol + P_7 dq_1 + P_{(8)}.ECP}$$

The results of the unconstrained estimation of the model indicate that the regressor coefficients fulfill the following constraints[13]:

$\mathbf{P_{3=}\ P_{11}}$

$\mathbf{(1\text{-}3{*}P_{11} - P_2)) = P_5}$

Our definition of the output-gap[14] in terms of the log-difference between potential and actual output implies a non-linear relationship between inflation and the output-gap, defined as the ratio between potential and actual output. This means that the marginal effect of the gap on prices is higher when economic activity is above potential than when it is

[12] See appendix 1 for the estimation results.

[13] The statistical results reported in Appendix 2 refer to the constrained estimation of the equation given that the above restrictions are fulfilled.

[14] For a definition of the output- gap see Djivre and Ribon (2000).

below potential. In the vicinity of full employment, a change in the output gap by one percentage point gives rise to a 0.2 change in prices on an annual basis.

This flattening of the Phillips curve indicates that an unexpected fall in prices is reflected in this case in a further expansion of the output gap, most probably as a result of firms going out of business, their personnel being fired and where a further reduction in prices in reaction to a slack in economic activity being useless.

The coefficient for the error correction component of the equation was statistically insignificant, indicating that shocks to prices are not corrected over time and it is nominal wages that adjust so as to equilibrate between real wages and labor productivity. Indeed the estimation results of the wage equation support this interpretation.

According to the estimation results the share of the purely tradable sector in the determination of the business sector gdp price inflation has a confidence interval between 2 and 18 percent. Of the remaining firms the majority, 67 per cent, are forward looking and the remaining 23 percent, are backward looking.

The gdp deflator inflation

This is an auxiliary equation linking the quarterly inflation in terms of the deflator of the business sector, **dlpgdp_bs**, to the quarterly inflation with respect to the general gdp deflator, **dlpgdp**.

We examined and found that these two variables are cointegrated in their levels and as a result the estimated regression should be the first difference of the long-run cointegration relationship augmented by an error-correction term, **ECP** and possibly other variables, like seasonal dummies, relevant in the short-run.

$$\textbf{(4) } dPgdp = pg(0) + pg(1).d_{951} + pg(2).dPgdp_{bs} - pg(3).ECPgdp(-1) + pg(4).dq_2 - pg(5).dq_4$$

The estimation results gave rise to a statistically significant but very small error correction coefficient as it can be seen in Appendix 1. Since expression (4) is equal in the long-run to the first difference of the cointegration equation, it is then clear that the coefficient pg(2) should be equal to the coefficient of the gdp deflator of the business sector in the cointegration equation. Indeed according to the estimation results the coefficient pg(2) was obtained as being equal to 1.03 while the coefficient of the corresponding level variable in the cointegration equation was found to be equal to 1.1.

The CP inflation

In case where the consumer good prices are determined competitively, the duality between prices and quantities implies that our assumption of a two stage production process, whereby consumption goods are produced using domestic product, **GDP,** and imported materials, is consistent with the following price equation. The consumer price index is its dependent variable and the gdp deflator and the price of imported materials in domestic currency are its dependent variables with elasticities that are identical to those of the corresponding inputs in the production function of consumption goods.

This equation plays the role of a cointegrating relationship between the CPI, the gdp deflator and the price of imported materials[15]. This implies that CP inflation could be expressed as the first difference of this cointegrating relationship augmented by an error correction factor, **ECCP**, and by other variables which may affect consumer price inflation in the short run such as seasonal dummies or lagged values of gdp or imported materials inflation. In this way the CP quarterly inflation, dp, could be expressed as a function of the gdp price inflation, **dlpgdp**, and of the inflation in the local currency price of imported goods. The latter is approximately equal to the sum of the change in the dollar price of

[15] Our hypothesis of the existence of a cointegrating vector among the above three prices, the consumer price index, the gdp deflator and the domestic currency price of imported materials is supported by the results of a special unit-root test conducted on the residuals of the co-integrating equation. In spite of the existence of a cointegrating relationship the estimation results of the consumer price inflation equation did not allow for the introduction of an error-correction component because its coefficient was not statistically different from zero.

imported gpoods, **dlpmi,** and of the change in the nominal exchange rate in dollar terms, **dldol**. In the estimated regression we have also allowed for changes in the timing with which exchange rate depreciation affects commodity price inflation during the estimation period and in particular following the transition to a floating exchange rate regime after 1997.

The duality principle implies that the introduction of dummy variables to account for a possible change in the relative weight of the imported materials prices over time and hence in the relative weight of the nominal exchange depreciation rate must be the result of a change in the technology of production. That is, requiring a similar change in the intensity in the use of the two production inputs, domestic product and imported materials. Absent such a technological change, the change in the relative weights of the prices of the two inputs is unjustified. The only possible change in the contribution of the price of imported materials, in general, and of the change in the exchange rate, in particular, to the CP inflation may arise as a result of changes in the delay (lag) with which changes in the exchange rate affect consumer prices. Such a change does not affect the long run configuration of the estimated regression and does not require as a result a similar change in the price cointegration equation and its dual representation - the production function. In view of the fact that the data did not support the first version of structural change in the production function, we adopted the second approach as it may be seen in expression (5):

$$\textbf{(5) } dP = p(0) - p(1).d_{973aft} - p(2).d_{951} + p(3).dPgdp(-1) + p(4).d_{973aft}.dldol$$
$$+ p(4).d_{973aft}.dlpmi + p(5).[dldol(-1) + dlpmi(-1)] - p(6).d_{973aft}.[dldol(-1) +$$
$$+ dlpmi(-1)] + p(7).dq_2 - p(8).dq_3 + p(9).dP(-1) + p(10).ECCP(-1)$$

The estimation results fulfill the following restrictions:

p(4)+p(6)=0 and

p(9)+p(3)+p(5) =1

The final estimation results reported in Appendix 2 have been obtained after imposing on the data these restrictions.

The first restriction implies that the effect of a change in the prices of imported materials on consumer price inflation is faster after 1997 while the second restriction implies a constant-returns-to-scale technology in the production of consumption goods.

The insignificance of the error-correction factor which was omitted from the final estimation implies that the deviation of consumer prices from the gdp deflator and from the prices of imported materials is not corrected by an adjustment of the former in the direction of the latter so that shocks to consumer prices do not reverse themselves. And it is rather the remaining components of the cointegration vector which adjust.

The long-run relative weights of gdp inflation and of imported materials inflation, after all lagged regressor values have been eliminated are 0.64 and 0.36 respectively.

From the estimation of the inflation price equations it transpires that the nominal exchange rate depreciation affects consumer prices in the short run both directly and indirectly. The direct effect is measured by the weight of imported material inflation in the estimated regression, which turns out to be 0.36, and the indirect effect refers to the exchange rate depreciation effect on GDP price inflation whose average elasticity in the estimation sample is 0.10. Given the weight of 0.64 of GDP price inflation in the consumer price inflation estimated here, we get an indirect exchange rate depreciation effect on consumer price inflation of the order of 0.064 so that the overall exchange rate depreciation effect on consumer price inflation is in the short run around 0.42.

The long-run version of the estimated regression is the first difference of the cointegration equation of the CP, the GDP price and the imported materials prices in domestic currency. This implies that the long-run coefficients of the GDP price inflation and of the imported materials inflation should be equal to the coefficients of the corresponding level variables in the cointegration equation. The latter are equal to 0.83 and 0.17 respectively (Appendix 1)[16].

<u>The inflation expectations equation</u>

The dependent variable in the estimated regression is the quarterly average of the twelve-month ahead expected consumer price inflation, **exp**, lagged by one month, exp_1. The expected rate of inflation is derived by imposing a no-arbitrage condition between returns on government-bonds indexed to the cpi and zero coupon nominal treasury bills (Makam) with the same maturity. The lagged (of one month) specification of expected inflation arises from the need to use the lagged value of expectations in the BoI interest rate equation. The reason for this lag derives from the fact that the BoI sets the interest rate for a particular month at the end of the previous month so that the corresponding expected inflation rate is the one available during the month preceding the month for which the interest rate is set by the central bank.

The estimated regression equation is of the form:

$$\textbf{(6)}\quad \mathbf{Exp\_1 = x(0) - x(1).d_{973aft} + x(3).(FI(-1) + FI((-2))/200 + x(4).dP(-1)*4}$$
$$\mathbf{+\, x(5).d_{973aft}dE*4 + x(6).AR(1)}$$

The conception behind the specification of the estimated regression equation is that the steady state inflation rate is determined in the long run by the size of the government budget deficit and by the ratio of the public sector's debt to the gross domestic product measured here by the variable FI (Fiscal_Index)[17]. Deviations from this long run rate may be the result of shocks or of monetary policy measures which can affect the inflation rate only in the short run and whose effect is measured here by the lagged value of quarterly consumer price inflation, **dp,** and in addition the nominal exchange rate depreciation, **DE,** following the transition to a pure float in July 1997 for which we use the dummy variable

[16] These values fall within the confidence interval of the long-run coefficients of the estimated regression equation.
[17] For a definition of this variable see: Dahan, M. and M. Strawczynski (1997).

d_{973aft}. The former variable may account for the backward looking component of the inflation expectations when they deviate from their steady state equilibrium level, while the exchange rate depreciation effect after July 1997 may be considered as accounting for the forward looking component of these expectations. The estimated equation includes also an autoregressive term, AR(1), to guarantee an i.i.d residual

The estimation results reported in Appendix 2 indicate that during the estimation period a one percentage point reduction in the fiscal index is reflected in a commensurate fall of the long run inflation rate[18]. The estimation results indicate also that a quarterly depreciation of the nominal exchange rate by one percentage point is consistent with a rise of expected inflation by 0.32 percentage points, after the transition to a pure float in 1997.

c.4 The nominal wage setting equation

The nominal wage adjustment equation is based on the notion that the workers in the business sector set their wages, based on their inflationary expectations, **exp,** as well as the labor market conditions measured by the level of domestic product, **Y**. Higher inflation expectations accelerate the process of wage inflation, **dw,** while lower economic activity decelerates this process.

$$dw = exp + F(y)$$

Linearizing F(y) around full-employment y* we get:

$$dw = exp + F(y^*) + F_1(y^*).(y - y^*)$$

Where F(.) is the function describing the partial effect of economic activity on wage setting. The second term of the linear approximation consists of a constant $F_1(y^*)$ (the derivative evaluated at y*) multiplied by the output gap y – y*.

[18] This calculation constitutes an approximation since the nominal exchange rate depreciation and the consumer price inflation are not necessarily identical in the steady state.

We require this short run wage-setting equation to satisfy in the long run the condition:

$dW = Exp + f_2 dprod^*$,

where Exp is equal in the long-run to the steady state inflation rate and dprod* is the long run productivity change. This restriction implies that F(y*) is proportional to dprod*, i.e. $F(y^*) = f_{2.}dprod^*$ with F_2 being a constant[19] to be determined in the estimation process.

We substitute these conditions into the short run wage-setting equation, expressed in terms of the rate of change of nominal wages per unit of labor input, **dw,** and we also include an error-correction component, Ecw, assuring the long-run convergence of real wages in terms of the business sector gdp deflator to a level equal to that of labor productivity.[20]

(7) $$dW = w(0) + w(1).dq_2 – w(2).d951 + w(3).dprod + w(4).exp/4 + w(5).dW(-4) – w(6).gap(-2) – w(7).Ecw(-1)$$

We have allowed additional dynamics in the estimation by including the dependent variable, dw, lagged by four quarters and two intercept dummies. The first one, $dq_{2,}$ accounts for a seasonal factor present in the second quarter and the second one, d951, is set equal to one in the first quarter of 1995 to account for a change in the classification of the wage data.

The original wage data were the monthly wage per working position which comprises hourly wage, the number of working positions per employee and the number of hours worked per week per employee. We transformed the data to hourly wages utilizing data on the number of hours worked per week in the business sector and the number of working positions per employee in the business sector for Israeli workers. The hourly wage

[19] F should be equal to unity under perfect competition.
[20] See discussion on the co-integration equation in the section on the business sector gdp-price inflation.

in the business sector refers, however, to foreign workers as well. Since some of the data on foreign workers are unavailable we based our calculations on the following assumptions:

a) the number of weekly hours worked by foreign workers in the business sector is proportional to that of local workers and constant over time.

b) the number of jobs per worker of foreign workers in the business sector is proportional to that of local workers and constant over time.

In the regression estimation the data are expressed in log terms so that the proportionality coefficients which have been assumed to be constant are accounted for by the regression intercept of both the long-run and the short-run equations.

The long run equilibrium properties of the estimated equation imply restrictions on its coefficients. In particular the long run coefficients of the expected inflation and of the productivity gains should be equal to unity, provided firms do not have monopolistic power over their employees and do not extract from them any rent.

The only constraint imposed initially in the estimation of equation (7) was the equality between the coefficients w(3) and w(4). The estimation results did not allow in this case the rejection of the additional constraint that w(3)+w(5)=1, a condition which implies a long run coefficient of unity for inflation expectations and for labor productivity and is consistent with RE in the long run and competitive labor renumeration[21].

Unlike the business sector gdp price inflation the coefficient of the error correction factor we obtained was negative and significantly different from zero implying that nominal wages are the variable which adjusts when the long run relationship between wages, prices and productivity is perturbed.

For reasons similar to those described in the section of the business sector price inflation, the output gap effect on the nominal wage inflation is non-linear and weakens together with the slack in economic activity.

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[21] The estimation results reported here are of the constrained version of the regression after our hypothesis that the coefficients of exp and dprod were found to be equal in the unrestricted version of the estimation.

c.5 The short-run productivity equation

This equation was estimated following the 2sls procedure outside our system of equations. with productivity gains, **dprod**, as the dependent variable, measured by a rise in the product per unit of labor input in logs.

According to the regression specification changes in labor productivity are determined by changes in real wages in terms of the gdp deflator of the business sector, **($dw - dgdp_{bs}$)** and by lagged productivity changes. In order to overcome the multicolinearity involved when the l the real wage and the productivity changes are both included in the estimated regression we regressed first the productivity gain, dprod, on the real wage and then used the residuals of this regression, **resdprod**, as a substitute for the lagged changes in productivity.

(8) $$dprod = cc(0) + cc(1).dW - cc(11).dPgdp_{bs} + cc(2).dW(-4)\ cc(22).dPgdp_{bs}(-4) - cc(3).resdprod(-4)$$

In spite of the existence of a cointegration vector the estimated regression equation has not been augmented by an error-correction component. The reason for the exclusion of this variable is because productivity is exogenous to wages and prices in the short run since it reflects the level of technology in a given economy which there is no reason to assume it fluctuates in tandem with changes in either nominal wages or in prices.

The long-run version of the estimated equation obtained, following the elimination of all lags present in it, should give rise to long-run unit elasticity between changes in productivity and real wages in line with the long-run cointegrating relationship between nominal wages, prices and productivity. This in spite of the fact that the implied error-correction factor has been omitted from the estimation.

The estimation was initially made by imposing the two following restrictions:

cc(1)+cc(11)=0, and **cc(2)+cc(22)=0.**

The estimation results obtained did not allow the rejection of the hypothesis that the long run value of the real wage coefficient was equal to unity, i.e. **cc(1)+cc(2)+cc(3)=1** and as a result the final estimated version of the equation, whose results are reported in appendix 2, included also this restriction. The positive sign obtained for the real contemporaneous wage could be interpreted as reflecting, at least to some extent, optimization considerations by the firm. More precisely we should expect higher real wages to go hand in hand with higher productivity since the optimizing firm is expected to raise the capital/labor ratio in response to a rise in real wages increasing thereby the output per unit of labor input.

c.6 The Bank of Israel interest rate

The nominal interest rate equation is an ad-hoc specification of the nominal BoI interest rate as in Djivre and Ribon (2000) that does not necessarily reflect an optimal interest rate rule derived from the minimization of a loss function by the central bank [Ball (1999), Cecchetti (1998) and Rudebusch and Svensson (1998)] but derives from the ad-hoc approach of Taylor(1993 and 1994). This implies that the regressor coefficients in the interest rate equation may reflect not only the preferences of the central banker among various targeted variables but also the underlying structure of the Israeli economy during the estimation paeriod.[22] According to Christiano et al. (1998) the interest rate reaction functions suffer from the observational equivalence problem, a criticism which implies that such equations may at best describe the evolution of central bank short-term interest rates. A similar criticism was raised recently by Minford et al (2001) who show that different policy rules may be expressed in terms of the output gap and of deviations of the inflation rate from the inflation target We do not consider therefore like Djivre and Ribon (2000)) the estimated

[22] For the determination of the central bank interest rate in Israel as a function of the unemployment rate and the deviation of inflation from its targeted level see also Gottlieb and Ribon (1999).

equation as a central bank reaction function in the strict sense of the term.

Our sample period comprises three regimes of monetary policy. The first one between 1990 and the formal adoption of inflation targeting in 1994, the second one between 1994 and the transition to a pure float in 1997 and the third one after 1997, when monetary policy was tightened further according to the estimation results. During the first four years, 1990-1994, the BOI was mainly concerned with the stability of the foreign exchange market and the growth of the economy. This policy was reflected in a systematically low real short-term interest rate which was negative during most of the period. The Israeli government and the BoI have adopted inflation targets since 1994 and the BoI has explicitly used its short-term nominal interest rate for the conduct of monetary policy (September 1994) abandoning the nominal exchange rate as the nominal anchor, an action which allowed greater exchange rate flexibility and the eventual transition to the pure float.

According to our formulation of the BoI interest rate equation the setting of the interest rate depended, prior to the adoption of inflation targets, on the output gap, on lagged values of the interest rate - to test for the possibility of interest rate smoothing, and on inflation expectations which reflected to a certain extent the public's expectations concerning the evolution of the nominal exchange rate which served at that time as a nominal anchor. It is the interdependence between expected inflation and changes in the nominal exchange rate and the use of the interest rate by the BoI to defend the latter's stability, that justifies the specification of the BoI interest rate equation during a period in which the Bank related to the monetary loan (to commercial banks) as its main monetary instrument. This specification is represented as follows

(9a) $$\mathbf{i_m = r(0) + r(1).exp\_1 + r(2).(gap(-1)+gap(-2))/2 + r(3).\ i_{m(-1)}}$$

Our specification allows for the explicit introduction of inflation targets after 1994, measured by the average inflation rate after the introduction of target bands, and for testing the hypothesis of a monetary tightening by introducing a dummy variable in inflation expectations after 1994. We have introduced a similar dummy for the period after 1997. Accordingly, the interest rate equation becomes

9(b) $\mathbf{i_m = r(0) + r(1).exp\_1 + r(11).d_{942aft}Exp\_1 + r(12).d_{973aft}Exp\_1}$

$\mathbf{+r(2).(gap(-1)+gap(-2))/2 + r(3).\ i_{m(-1)} + r(4).d_{942aft}Target + r(5).d1 + r(6).d2 +}$

$\mathbf{r(7).d3 + r(8).d_{91q4} + r(9).\ d_{02q1}}$

We have also included in the estimated version of the equation four intercept dummies, **d1, d2, d3 and** $\mathbf{d_{91q4}}$,to account for short and distinct periods of speculative attacks on the managed exchange rate regime and exchange rate crises such as the one in the last quarter of 1998[23]. The inclusion of these dummies, is justified because when the BoI reacted to the exchange rate crises, expectations fell back eventually, following their initial rise, and as a result the quarterly average inflation expectations level could not account for the high BoI interest which was reduced afterwards only gradually. We also used an additional dummy variable, $\mathbf{d_{02q1}}$, to account for the unanticipated interest rate reduction by the BoI in the first quarter of 2002. The sign of the speculative dummies should be positive while that of the 2002 dummy should be negative.

Rearranging terms we may rewrite equation (9b) as a Taylor rule after 1994 and 1997, respectively, as follows after ommitting for reasons of simplicity the dummy variables:

For 1994 - 1997

(9c) $\mathbf{i_m = r(0) + [r(1) + r(11) - r(4)].Exp\_1 +}$

[23] The other three dummy variables refer to the periods: 1990.1, 1991.4 and 1992.4

$$r(2).(gap(-1)+gap(-2))/2 + r(3).\, i_{m(-1)} + r(4).(-Exp\_1+Target)$$

Following 1997

$$\textbf{(9d)} \quad i_m = r(0) + [r(1) + r(11) + r(12) - r(4)].Exp\_1 +$$

$$+ r(2).(gap(-1)+gap(-2))/2 + r(3).\, i_{m(-1)} + r(4).(-Exp\_1+Target)$$

The estimated coefficients have all the expected sign, including the dummy variables, and they indeed confirm the hypothesis of a gradual monetary tightening both after 1994 and 1997. More precisely **r(2)** and **r(4)** are negative while **r(1), r(11), (12)** and **r(3)** are positive. The specification of the estimated equation for the three monetary policy regimes after all lags have been eliminated is as follows:

1989.4-1994.2

$$\textbf{(9e)} \quad i_m^* = 0.054 + 0.563Exp^*$$

1994.3-1997.3

$$\textbf{(9f.1)} \quad i_m^* = 0.054 + 2.032Exp^* - 1.268Target^*$$

1997.3 2002.2

$$\textbf{(9g.1)} \quad i_m^* = 0.054 + 2.630Exp^* - 1.268Target^*$$

An interpretation of the estimated regression as a Taylor rule allows us to consider its intercept as an estimate for the long run short-term real interest rate which after taking into consideration the interest rate smoothing effect is equal to 5.4 percent.

Expressions (9f.1) and (9g.1) indicate that after 1994 a rise in inflation expectations was accompanied by interest rate increases that overcompensated for the rise in expected inflation leading to higher short term real interest rates. However the same expressions seem to indicate that the coefficient of inflation expectations, after taking into consideration deviations from the inflation target, is close but still lower than unity after 1994 and close but significantly higher than unity after 1997[24]. In other words the estimation results do not confirm the hypothesis that the conduct of the monetary policy by the BoI fulfills in the long run the Fisher equation. It is possible to reconcile the data with economic theory by rearranging terms in expressions (9f.1) and (9g.1) as follows:

(9f.2) $\mathbf{i_m^* = (0.054-.236.Exp^*) + Exp^*+1.268.(Exp^* - Target^*)}$

(9g.2) $\mathbf{i_m^* = (0.054+0.362.Exp^*) + Exp^*+1.268.(Exp^* - Target^*)}$

The interpretation to be given in this version of the estimation results is that the monetary policy followed by the BoI between 1994 and 1997 was such that it aimed at a steady-state short-term interest rate lower than average, by a factor equal to **0.236.Exp*,** while after 1997 it aimed at a steady-state real interest rate higher than average, by a factor equal to **0.362.Exp*,** fullfilling at the same time the Fisher equation.

c.7 The debitory short term interest rate

Commercial banks in Israel set the interest rate they charge on loans using the interest rate set by the BoI on liquid funds as a benchmark. Commercial banks add a constant mark-up to this benchmark, reflecting their monopoly power in the market for loanable funds, which is supplemented by a risk premium. This pricing policy stands behind the specification of the estimated regression whose dependent variable is the short-term commercial bank nominal interest rate on lines of credit.

(10) $\mathbf{i_{hhd} = ih(0) – ih(1).d_{91aft} + ih(2).i_m + ih(3).i_{hhd}(-1) + [ih(4).AR(1)]}$

[24] A Wald test on the regression coefficients indicates that the sum of the coefficients of the inflation expectations and of the lagged interest rate is significantly greater than unity not only after 1997 but after 1994 as well.

The estimated regression includes also an intercept dummy variable to account for the period following 1991, during which capital flows to and from Israel were gradually liberalized, starting with foreign currency indexed and denominated credit. The estimation results indicate that the dummy coefficient is indeed negative and of a considerable magnitude in the long run, 7.1 percentage points, implying that the opening of alternative sources of credit apparently weakened the commercial bank monopolistic power by creating a mechanism of market contestability.

The pricing policy we stipulated requires that the specification of the estimated regression should give rise in the long run to a coefficient for the BoI interest rate which is equal to unity, a condition fulfilled when ih(2)+ ih(3) =1. Contrary to this pricing policy, the unconstrained estimation of the regression equation in the context of our model gave rise to a long run coefficient for the BoI interest rate which is slightly higher but significantly so than unity[25].

III. <u>Goodness of fit and Impulse response functions.</u>

a. The goodness of fit

To assess the goodness of fit of our model we performed a within the sample dynamic simulation. Had the regressor coefficients changed considerably during the period under consideration, we would have expected long horizon forecasts to deviate considerably from actual values as a result of the aforementioned hypothesized structural break. This implies of course that the goodness of fit reflected in the residuals of the estimated regressions would have been also rather poor. Indeed the information included and revealed by such a dynamic simulation is identical to the information conveyed by the estimation residuals.[26]

[25] The estimation results reported in Appendix 2 were obtained following the imposition of the unity constraint

[26] Pagan (1989).

In this respect it may be said that the dynamic simulation constitutes just a more illustrative and illuminating method of examining the goodness of fit of the estimated model (Diagram 2).

The dynamic simulation results indicate that in most cases our model succeeds in replicating the actual changes in the direction of the evolution of the endogenous variables. However some remarks are still in order.

a) Our model performs rather poorly in the case of nominal wages. The reason for this poor performance may be attributed not so much to the poor performance of the wage equation but mainly to the poor performance of the productivity equation.

b) The forecasts for inflation and inflation expectations for the years 1992-1994 are high relatively to the actual evolution of these two variables and they imply that our model does not account satisfactorily for the fall in inflation rate after 1991. This deviation affects also the values of the ex-post real interest rate which are relatively low to the actual values as a result of the corresponding inflation rate being too high, giving rise to relatively low output-gap forecasts obtained for the same years.

The conclusion to be drawn from this exercise is that our model exhibits in general a good fit and that an effort should be made to account for the drop in inflation after 1991 and an alternative approach for the calculation of productivity and of changes thereof could improve the model's performance in the case of wages. An alternative approach to the one implemented here for the estimation and calculation of the changes in productivity may be its direct calculation on the basis of an estimate of labor employment. More precisely, since productivity has been defined as the business sector GDP per unit of labor input, a direct forecast of the labor force employed together with the derivation of the gdp of the business sector from the forecast of the output gap may allow the calculation of labor productivity and changes thereof on the basis of its definition.

b. The impulse response functions

In this section we present the impulse response function to shocks in the interest rate of the BoI. The objective of this exercise is to provide a general characterization of the transmission mechanism of monetary policy emphasizing the sequence of changes observed from the time there is a change in monetary policy until the time this change is reflected in a change in prices and in economic activity.

In view of the policy changes described in previous sections we present here the impulse response function under the monetary regime which prevailed after 1997.3.

According to the impulse response function results (Diagram 3) an initial increase of the interest rates by the BoI leads on impact to higher nominal and real short term credit interest rate and lower nominal and real exchange depreciation rates The nominal exchange rate appreciation does also lead to an immediate fall in the gdp deflator because of the negative effect of the appreciation on the domestic currency price of exporting firms leading on impact to a real wage increase. The nominal exchange rate appreciation is also reflected in lower CP inflation, which is enhanced in the subsequent period by the mitigating effect of lower business-sector GDP inflation, and in lower inflation expectations (effect non-existent before 1997), which are further lowered in the subsequent quarter because of the lagged effect of the fall in consumer prices.

It is interesting to compare in this respect the behaviour of CP inflation and inflation expectations on the one hand and of business sector GDP inflation on the other. The IRF data indicate that the CP inflation lies behind the business sector GDP price inflation. This is due to the same factor which finds expression in both the exchange rate and the output-gap channel of the monetary policy transmission mechanism to prices. This factor is the one quarter lag with which GDP price inflation affects CP inflation.

In this way that part of the exchange rate appreciation (depreciation) effect which affects CP inflation through GDP price inflation does so with a one-quarter lag. By the same token the output gap affects CP inflation only through its effect on the business-sector GDP price inflation and as a result any change in the output gap affects first GDP inflation and only afterwards is it expressed in the CP inflation.

In the quarter following the shock the real exchange rate appreciation starts affecting economic activity. This effect builds up in the following quarters and reaches its maximum five quarters after the shock, only after the real exchange rate and the real interest rate have their full effect on economic activity, the real exchange rate remaining relatively higher than its unperturbed level for 10-11 quarters.

At this stage the central bank is in a process of reducing gradually the interest rate, a policy which supports a gradual process of deceleration of the nominal and real exchange rate appreciation. However the rising output-gap exerts pressure on prices and these renew their downward trend after the exchange rate appreciation effect on prices dissipates itself, reaching a second trough but relatively smaller than the first one, 10-11 quarters after the initial shock for the business-sector GDP price inflation and 15 quarters for the CP inflation.

Besides the aforementioned lead of the business-sector GDP inflation it is also interesting to note two additional stylized facts of the inflation process. CP inflation rises above its unperturbed level before renewing its downward trend because of the output gap. The reason is to be found again in the fact that the output-gap affects first and directly the business sector price inflation and only indirectly and with a lag the CP inflation. This allows the process of increasing prices to go on before the mitigating effect of the output-gap sets in. The second stylized fact is that the new round of falling prices is more substantial in the case of CP inflation than in the case of business-sector GDP price inflation. The reason for this effect is to be traced in a second round process of nominal and real exchange appreciation which coincides better with the CP inflation cycle. This process starts at the 11th quarter after the initial shock, following the dissipation of the output-gap effect on the real exchange rate depreciation, which fits better with the CP inflation cycle.

We may therefore differentiate between two distinct stages in the process of inflation deceleration, following an interest rate increase, appearing as an inverted double hump in the corresponding inflation impulse response functions. The immediate effect is due to the nominal exchange rate appreciation and the second round effect arises from the gradual widening of the output gap because of the real appreciation and the higher real interest rates.

The first stage in the slow-down of inflation deceleration is characteristic to small and open economies while the second round effect constitutes the main channel of transmission of monetary policy to prices in large and relatively closed economies.

The convergence process is based on the gradual reduction of the nominal interest rate by the central bank which is reflected in a slow fall of the short-term real interest rate because of the continued fall in prices which weakens the rate of downward adjustment of the real interest rate. The central bank reduces its interest rate below the convergence level because of the fall in prices and the curbing of inflation expectations but not enough to secure a substantially lower real interest rate.

The widening output gap has brought about a real exchange rate depreciation which supports the expansion of economic activity providing an additional economic force pushing the economy towards equilibrium. In fact after the downturn in economic activity which lasts for about 11 quarters a mild overheating in economic activity is observed because of the lagged effect of the aforementioned aforementioned real exchange rate depreciation which keeps the real exchange rate above its convergence level for 14- 15 quarters, with a maximum upward divergence of almost thirty basis points11 quarters after the shock.

The convergence process to equilibrium may be therefore considered as arising from the gradual reduction of the nominal interest rate which gives rise to an even slower fall of the real interest rate due to the continued fall in prices because of weaker economic activity and to the real exchange rate depreciation brought about by the slowdown in economic activity.

IV. Policy changes and the transmission of monetary policy

In this section we examine the way in which changes in the exchange rate and the monetary policy regimes affected the evolution of economic activity and of inflation during the estimation period and in their contribution to changes in the different channels of the transmission mechanism of monetary policy to inflation.

Output-gap vs. Inflation under different policy regimes.

1 Dynamic Forecasts

The first exercise consists in tracing the evolution of the economy by performing dynamic forecasts under the three different policy regimes over a given time period assuming that these regimes remain unaltered during this period. This exercise allows us to compare inflation-output-gap pairs at given dates (1994.III-2002.1) under different policy regimes.

It should be mentioned at this point that this exercise is hypothetical in the sense that it allows us to compare potential alternative paths of evolution for economic activity and inflation under different policy regimes and not actual paths. From this point of view this exercise cannot provide an exact evaluation of the costs of disinflation involved in the actual monetary policy conducted by the central bank but it can serve only as a benchmark for calculating the potential cost of such a policy given the path of the exogenous variables.

The results of this exercise indicate clearly that the policy regime adopted after 1997 allows a much more substantial reduction of the inflation rate at the price however of a higher output-gap (Diagrams 4). We present here the relative cost-benefit analysis of the monetary policy regimes[27].

[27] In this respect we do not differentiate between changes in the setting of the interest rate by the BoI and other changes were more closely related to the nominal exchange rate evolution such as its effect on the CP inflation, its sensitivity to changes in the interest rate differential and its effect on inflation expectations after 1997.

From the results of the dynamic simulations performed it transpires that at the end of the period the economy experienced a rise in the output gap, regardless of the monetary policy stance, most probably as a result of changes in these exogenous variables which include the intercept dummies. This implies that our calculations may tend to overestimate the cost of disinflation especially in the case of the cumulative output loss as a result of attributing the cost arising from the evolution of the exogenous variables to the different policy regimes. For this reason we decided to present our calculation in difference terms as it will be explained below. This approach allows us to eliminate to a certain extent the contribution of the exogenous variables, common to all three simulations, to the widening of the output gap.

For every quarter we calculated the difference between the level of activity under the 1997 regime on the one hand and the 1990 and the 1994 regime on the other. A similar calculation was made for the four quarter moving average of the inflation rate. In this way we obtained on a quarterly basis the relative inflation gain (loss) and its corresponding cost in terms of foregone (gained) economic activity. These two quarterly calculations were used in their turn to calculate the relative sacrifice ratio, namely the relative quantity of domestic product foregone as a result of an inflation rate reduction of one percentage point. Following the calculation of this ratio on a quarterly basis we calculated the average ratio over the whole period and overselectd sub-periods as reported in Table 1.

Table 1: Loss of output per percentage point of Inflation.

Policy Regime	**1994.3-2002.1**	**1994.3-1996.1**	**1996.2 2002.1**
1997 vs. 1990	**-.50**	**-.42**	**-.52**
1997 vs. 1994	**-.17**	**-.28**	**-.14**

From the results of this exercise it transpires that the 1994 regime was relatively inefficient. This fact is seen in Diagram 4 and is also supported by the relative low relative cost of disinflation obtained for the shift from the 1994 to the tighter 1997 regime when the quarterly average of annual inflation fell approximately by 8.5 percentage points.

With respect to the 1990 regime the output loss was more substantial while the extent of disinflation obtained in the dynamic simulation was almost the same.

We should alwys bear in mind that this exercise is hypothetical in the sense that it allows us to compare potential alternative paths of evolution for economic activity and inflation under different policy regimes and not actual paths.

2. The effects of the regime changes on the impulse responses to monetary policy shocks

This section will be presented in the lecture

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Diagram 2. Dynamic Simulation:1990.1-2002.1

Actual Values--------- Forecast Values ________

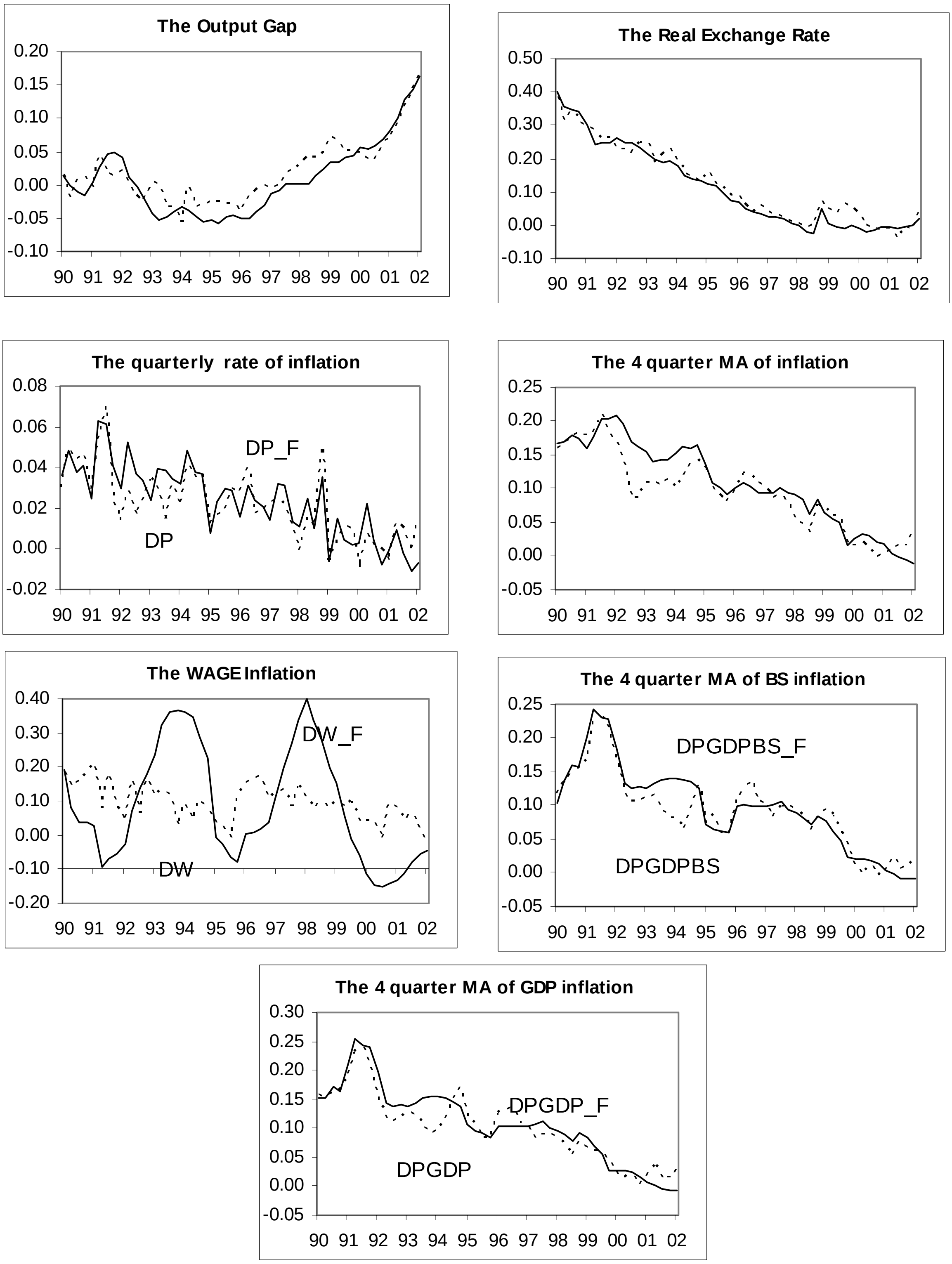
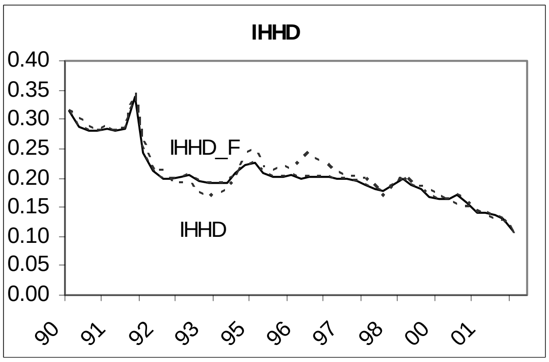
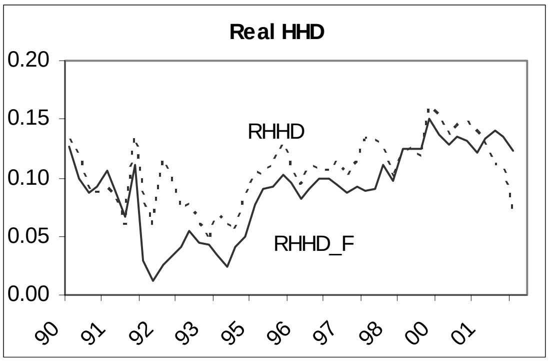
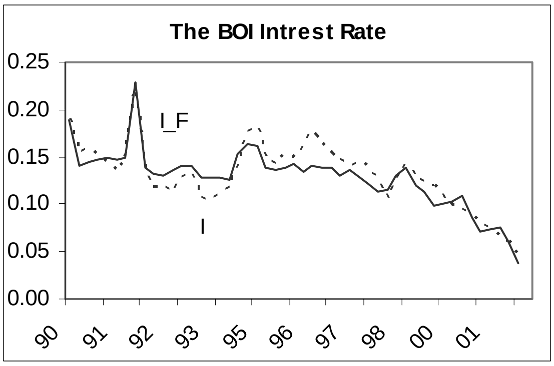
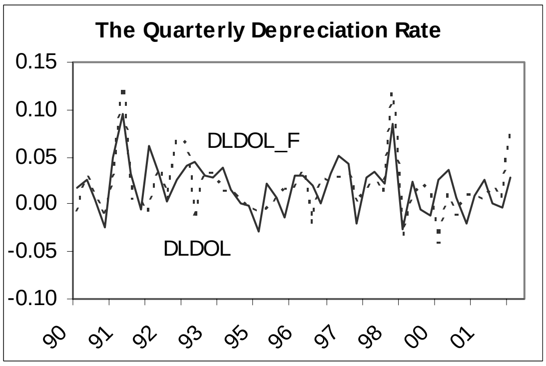


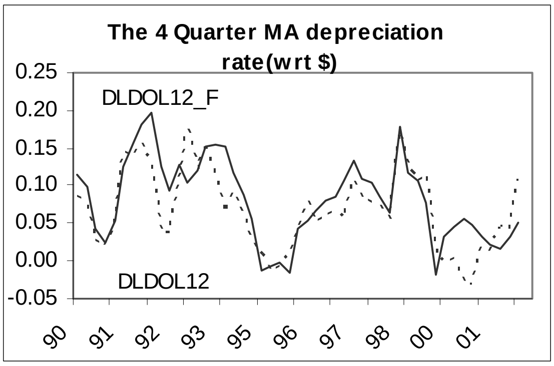
Diagram 2 (cou'd)

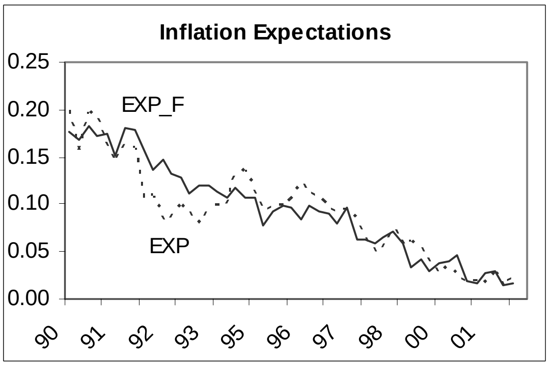












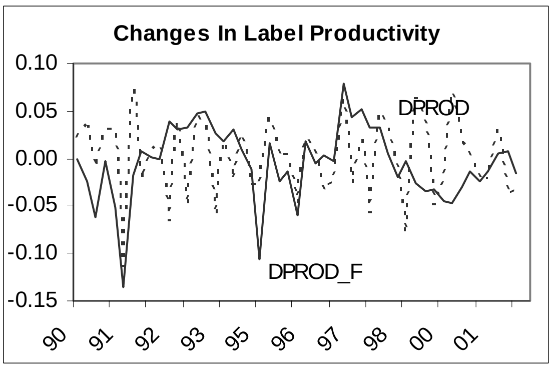
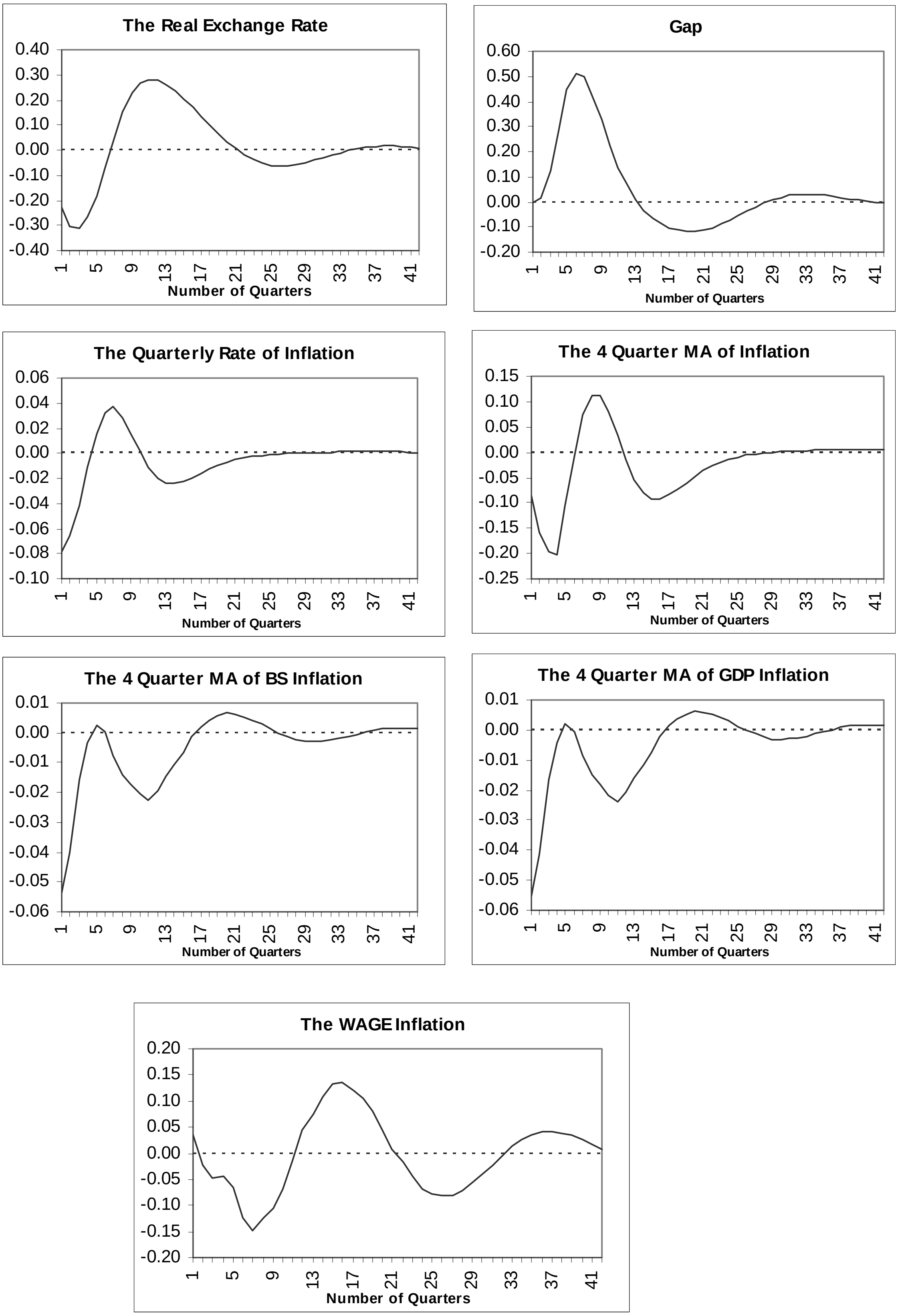


Diagram 3: Characterization of Monetary Policy

IRF to Shocks in the BOI Intrest Rate



(con'd)

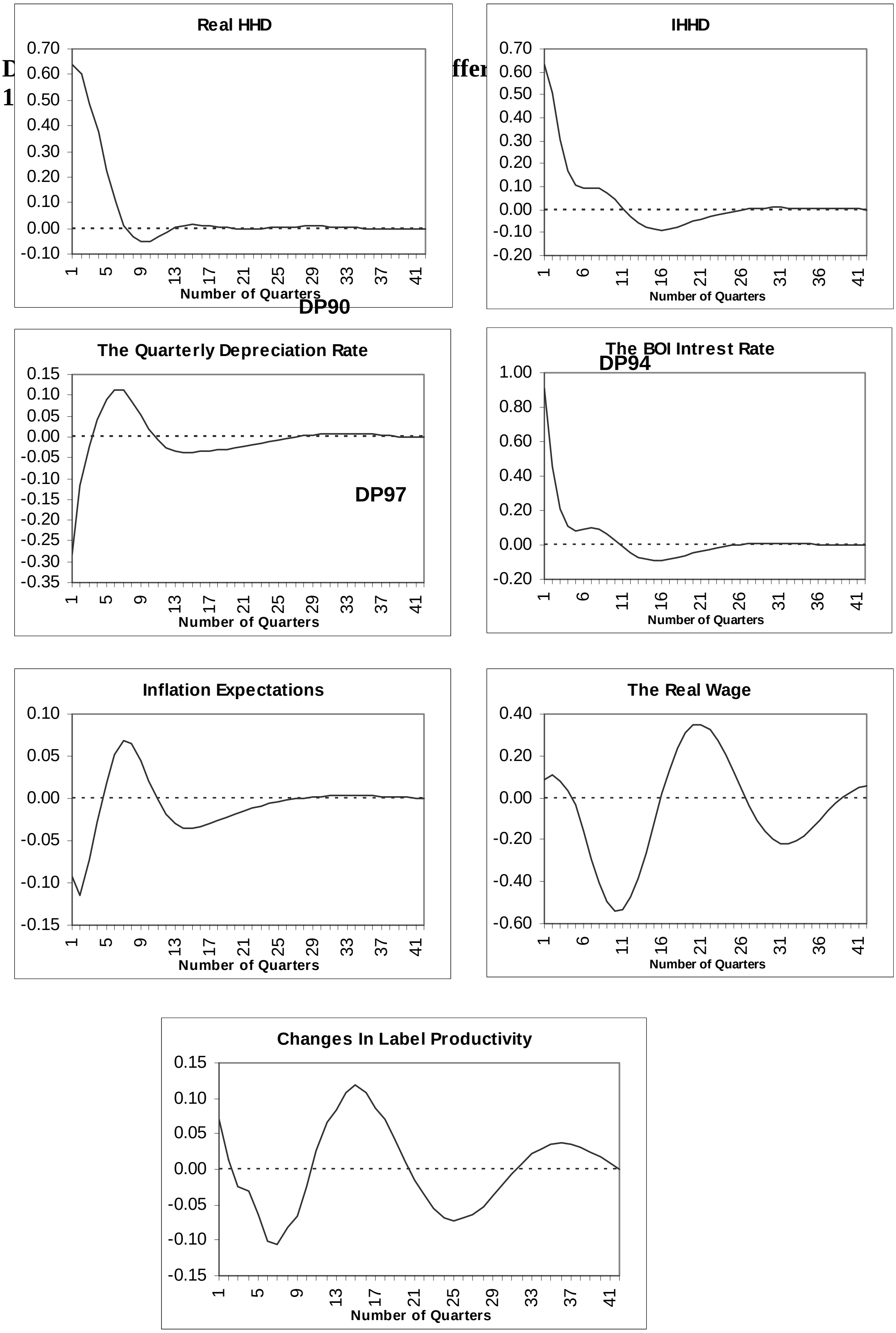
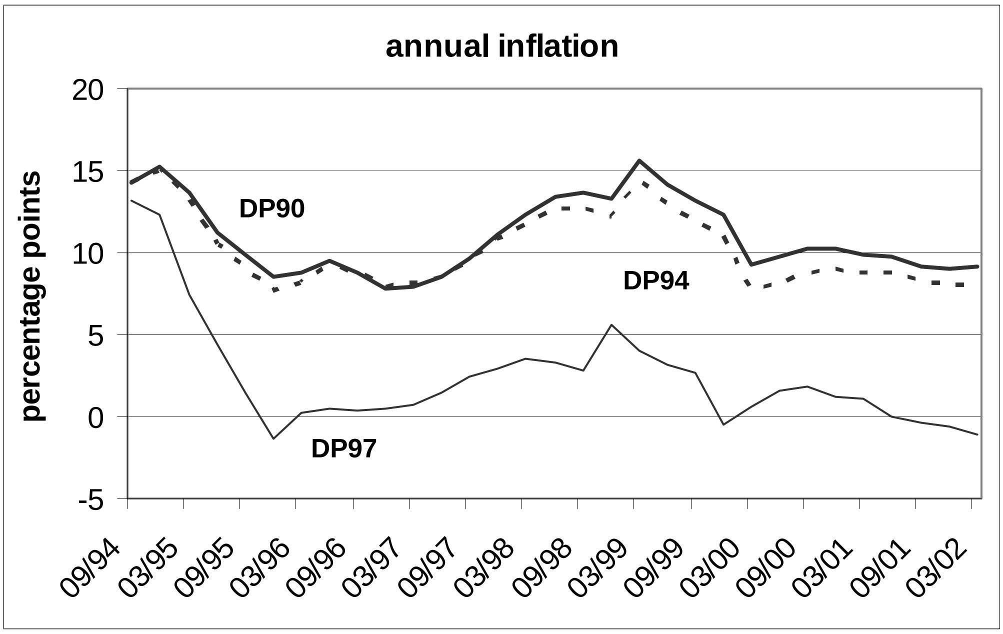
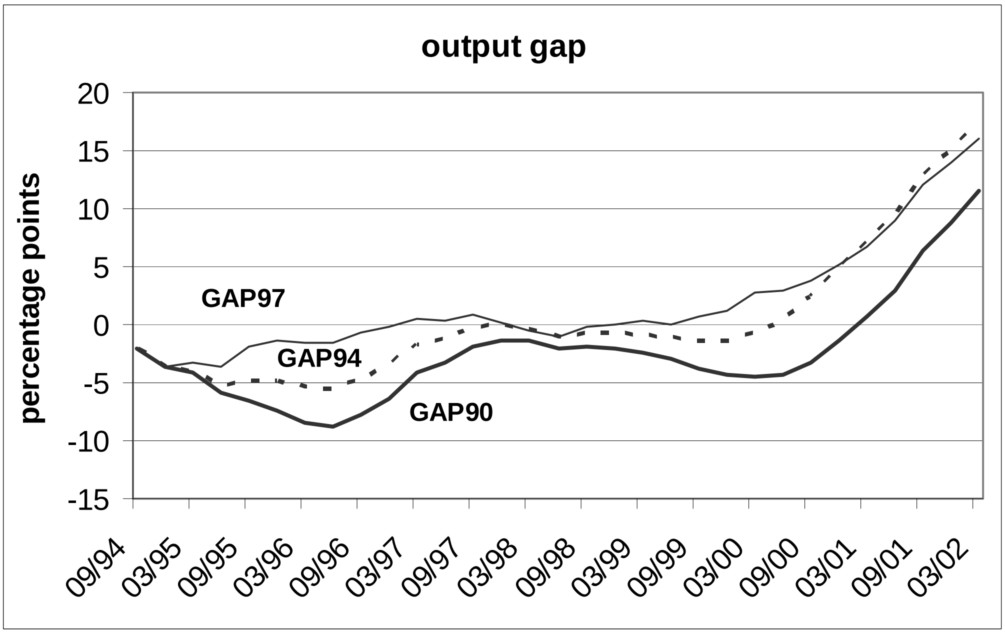
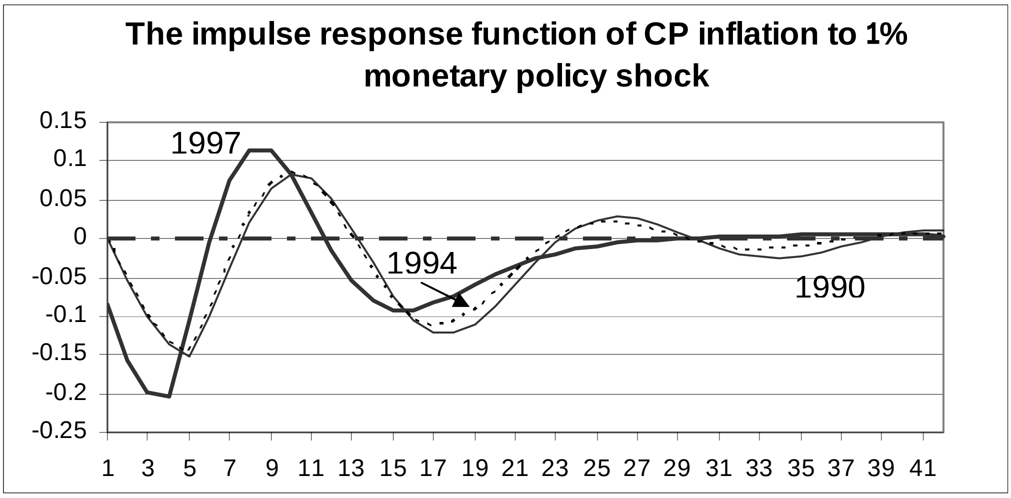

Real HHD
Number of Quarters
IHHD
Number of Quarters
DP90
The Quarterly Depreciation Rate
DP97
Number of Quarters
The BOI Intrest Rate
DP94
Number of Quarters
Inflation Expectations
Number of Quarters
The Real Wage
Number of Quarters
Changes In Label Productivity
Number of Quarters

Diagram 4: Dynamic simulations under different policy regimes 1994:3-2002:1

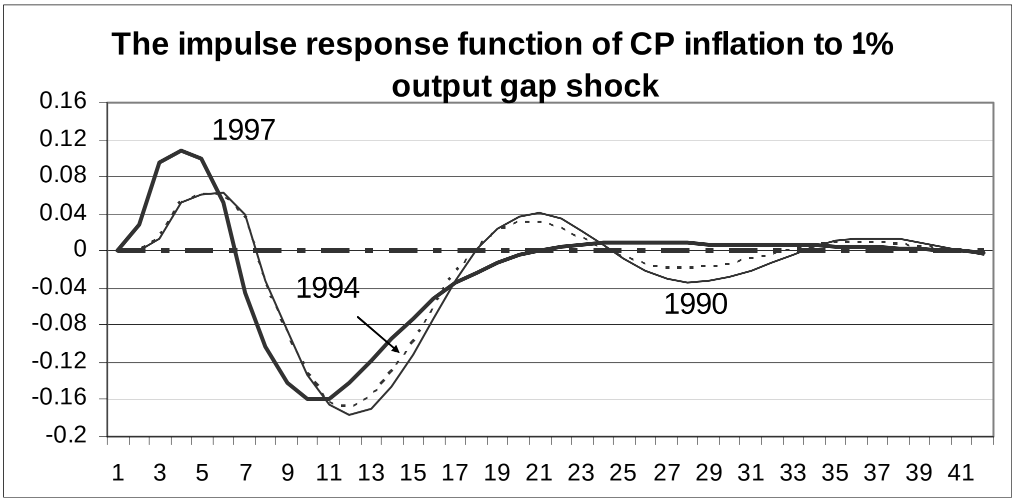




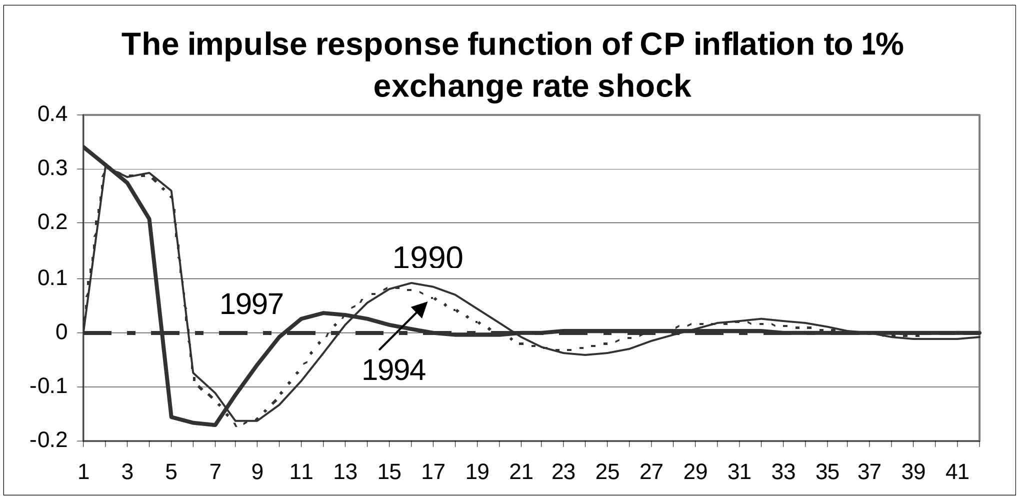
Diagrams 5A.



The impulse response function of CP inflation to 1% monetary policy shock
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
1997
1994
1990
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41

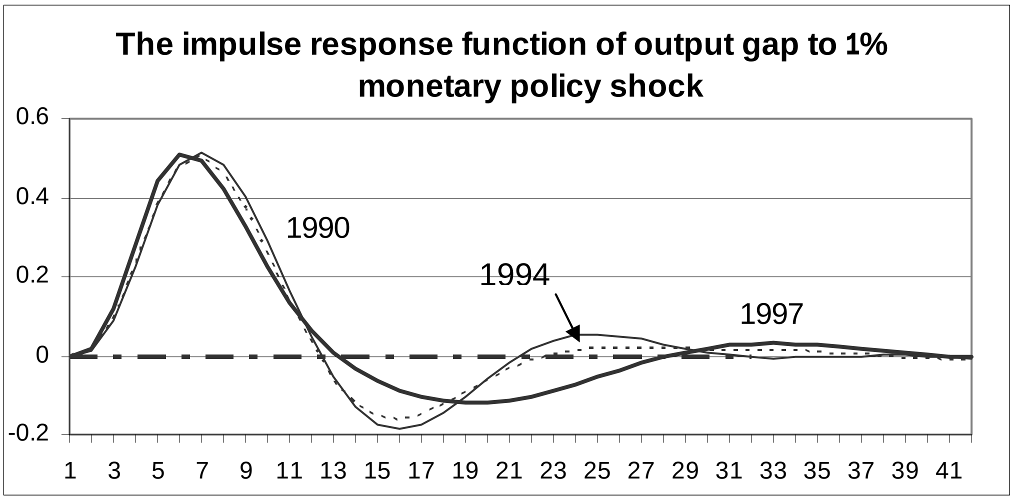


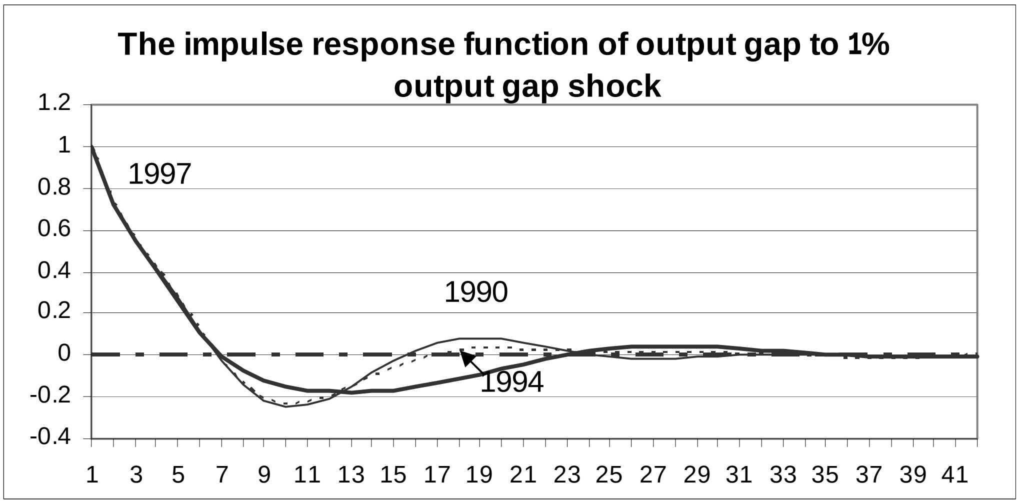
The impulse response function of CP inflation to 1% output gap shock
0.16
0.12
0.08
0.04
0
-0.04
-0.08
-0.12
-0.16
-0.2
1997
1994
1990
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41

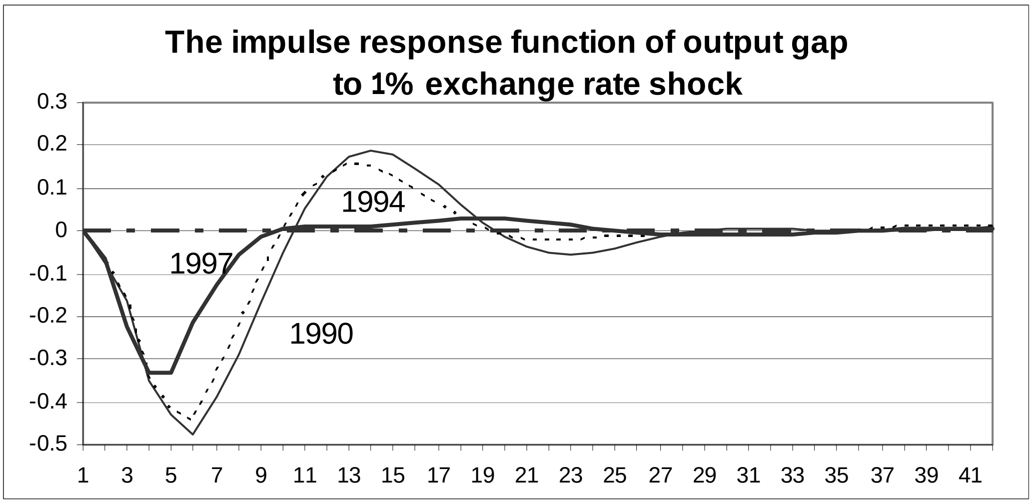


The impulse response function of CP inflation to 1% exchange rate shock
0.4
0.3
0.2
0.1
0
-0.1
-0.2
1990
1997
1994
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41

Diagrams 5B.


The impulse response function of output gap to 1% monetary policy shock
0.6
0.4
0.2
0
-0.2
1990
1994
1997
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41


The impulse response function of output gap to 1% output gap shock
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
1997
1990
1994
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41


The impulse response function of output gap to 1% exchange rate shock
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
1994
1997
1990
1 3 5 7 9 11 13 15 17 19 21 23 25 27 29 31 33 35 37 39 41

Appendix 1

We report below the estimation results for the three cointegration equations from which we have derived the error correction components used in the regression equations of the estimated system.

1. The GDP equation

LPGDP= 4.618 + 1.098* LPGDP _BS_HT
(.0062) (.0067)

DW: 0.63

Sample period: 1988.1 2002.2

LPGDP _BS_HT = The business sector gdp deflator including start-up companies.

The residual of this equation lagged by one quarter serves as the error-correction component in the GDP price inflation equation.

2. The real exchange rate equation

LPXNPGDP= 2.346 – 1.027*TFP_DIF – 1.209*log(RGDP/POP)
(.5688) (.1874) (.1552)

-0.643*log(RGOGDS/RGDP)
(.0687)

DW: 1.23

Sample period: 1988.2 2002.1

The residual of this equation lagged by one quarter serves as the error-correction component in the Real exchange rate depreciation equation..

TFP_DIF= Productivity differential between the tradable and the non-tradable goods sectors.

RGDP/POP = Real Income per capita.

RGOGDS/RGDP = The ratio of public sector civilian purchases to GDP

The specification of the long-run cointegration equation derives from De Gregorio et al.(1994) who have used income per capita and the civilian government expenditure as demand factors which may determine the long-run real exchange rate.

3. The wage-price-productivity equation

LHRWPRV2= 3.807 + 0.845*PROD + 1.061*LPGDP_BS_HT – 0.072*D9196
(.0112) (.1094) (.0174) (.0110)

DW: 1.39

Sample period. 1989.4 -2002.2

The residual of this equation lagged by one quarter serves as the error-correction component in the nominal wage inflation equation.

Prod = business sector product per unit of labor input.

LPGDP_BS_HT= The business sector gdp deflator including start-up companies.

D9196 = 1 if $19992.1<t<1997.1$ and 0 otherwise.

The residuals obtained in the regression estimation without the dummy variable, d9196, exhibited a U-shape pattern and were not white noise. We attributed this behaviour of the residuals to the influx of foreign workers not properly registered. As a result of the improper registration of foreign workers the measured output to whose production they have contributed is taken into consideration while their labor input is not. The obtained labor productivity obtained in this way is too high or nominal wages which reflect the influx of foreign workers are too low giving rise to the observed negative residuals. To neutralize the effect of the afore mentioned influx given the small number of observations we used as a regressor the dummy variable for the years this influx was on the rise and had not yet stabilized.

4. The CP-GDP deflator-Imported materials price equation

Log(CP) = -0.205 + 0.829.LPGDP + .171.(Ldol+LPMI)

CP = Consumer Price Index.

LPGDP = Log of the GDP deflator.

Ldol = Log of the U.S dollar exchange rate.

LPMI = Log of the dollar price of imported materials.

DW: 1.12 , Sample Period: 1988.1 2002.2

Appendix 2

I.List of Variables

* prefix L for natural log
* prefix D for difference
* suffix _S for seasonal adjustment
* suffix _MAx moving average for x quarters.

CP	-Consumer prices.
DP	- Quarterly CPI inflation rate.
DPGDP	- Quarterly GDP price inflation rate.
DPTAR	- Inflation target for current year.
DP12	- Inflation rate in past 12 months.
DLOL	- Dollar/Shekel exchange rate depreciation
Dlpmi	- The change in the price of intermediate goods in dollar terms.
$Dpgdp_{bs}$	Quarterly business sector GDP inflation rate.
Dprod	- Change in Labor productivity.
DUMQq	- Dummy variable for q quarter.
D91aft	- Dummy variable =1 starting from 1992Q1.
Dumagap3_12	=1 if MA(gap(-1),2)>.003 and 0 otherwise.
Dumagap3_2	= 1 if gap(-2)>0.003 and 0 otherwise.
dw	- Nominal wage rate of change.
Dyyq	- Dummy variable =1 for year yy quarter q.
Dyyqaft	- Dummy variable=1 after year yy quarter q.
ECx	- Error correction factor of variable x.
Eurosal	- Lending rate on foreign currency denominated credit.
Exp	- Expected inflation 12-months ahead.
Exp1	- DPE lagged one month.
FI	- Fiscal index: average of fiscal stance index (according to potential output) and public debt, averaged for past 3 years (see Dahan and Strawczynski (1997))
GAP	- The output gap. The ratio between potential output of the business sector and actual output.
Ihhd	- The nominal interest rate on short term credit.
Pdefgdp	- Government local budget deficit (percentage of GDP).
RGOGDS/RGDP	- Real Government civilian purchases over Real gdp
i_m	- BoI interest rate.
LPMI	- The price of imported intermediate goods in dollar terms.
POP	- population
P^*_{iexp}	- Export prices (in dollar terms).
PGDP	- GDP deflator.
Pgexp	_-dollar prices

Prod	- Labor productivity: GDP per labor input
rhhd	- Real interest rate on short-term credit.
RER	- Real exchange rate
Target	- The inflation Target
Tfpres1	- The residuals from the long run cointegration equation of the real exchange rate..
Tour_entry	-Number of tourist entries in Israel.
Tour_us	- Tourists in USA.
WT	- The volume of world trade.

II. The Estimation Results

The t-values appear in parenthesis below the regression coefficients.

1. The Output-gap Equation

$$\mathbf{gap} = -\underset{(0.035)}{0.216} - \underset{(0.053)}{0.219}MA(tfpres1(-1),3) + \underset{(0.052)}{0.238}MA(rhhd(-2),3)$$

$$- \underset{(0.100)}{0.166}MA(\log(wt(-1)) - Lwt\_hp(-1),3) - \underset{(0.009)}{0.056}MA((\log(tour\_entry)$$

$$- \log(tour\_us)),4) - \underset{(0.112)}{0.532}MA(pdefgdp(-2),4) + \underset{(0.069)}{0.694}gap(-1) - \underset{(0.111)}{0.282}AR(1)$$

Adjusted R^2 : 0.87 D.W. = 2.09

2. The Real Exchange Rate Depreciation Equation

$$dRER = \underset{(0.013)}{0.031} - \underset{(0.081)}{0.189}Rer(-1) - \underset{(0.055)}{0.279}tfpres1(-1) - \underset{(0.071)}{0.255}i_{hhd} + \underset{(0.071)}{0.255}eurosal$$

$$- \underset{(0.054)}{0.107}d_{973aft}\, i_{hhd} + \underset{(0.054)}{0.107}d_{973aft}eurosal + \underset{(0.096)}{0.460}D(\log(pgexp))*(1+1/\log(T))$$

$$+ \underset{(0.077)}{0.208}gap(-2) + \underset{(0.015)}{0.077}d_{98q4}$$

Adjusted R^2 : 0.50 D.W. = 2.18

3. The Business-Sector Price Inflation Equation

$$dPgdp_{bs} = -\underset{(0.002)}{0.003} + \underset{(0.006)}{0.031}d_{9112} - \underset{(0.010)}{0.032}d_{951} + \underset{(0.020)}{0.223}Exp$$

$$+ \underset{(0.053)}{0.230}MA(dW\text{-}dprod,2) - \underset{(0.020)}{0.223}(dPgdp_{bs}(-1) + dPgdp_{bs}(-2))/2$$

$$- \underset{(0.032)}{0.056}MA(gap(-1),2) + (1-3*\underset{(0.020)}{0.223} - \underset{(0.053)}{0.230}))dldol + \underset{(0.002)}{0.008}dq_1$$

Adjusted R^2 : 0.68 D.W. = 2.39

4. The GDP Price Inflation Equation

$$dPgdp = -\underset{(0.002)}{0.001} + \underset{(0.008)}{0.021}d_{951} + \underset{(0.082)}{1.027}dPgdp_{bs} - \underset{(0.051)}{0.097}ECPgdp(-1)$$

$$+ \underset{(0.002)}{0.017}dq_2 - \underset{(0.002)}{0.009}dq_4$$

Adjusted R^2 : 0.84 D.W. = 1.93

5.The CP Price inflation Equation

$$dP = \underset{(0.002)}{0.003} - \underset{(0.002)}{0.005}d_{973aft} - \underset{(0.008)}{0.026}d_{951} + \underset{(0.082)}{0.364}dPgdp(-1) + \underset{(0.031)}{0.276}d_{973aft}dldol$$

$$+ \underset{(0.031)}{0.276}d_{973aft}dlpmi + \underset{(0.044)}{0.204}(dldol(-1) + dlpmi(-1))$$

$$- \underset{(0.031)}{0.276}d_{973aft}(dldol(-1) + dlpmi(-1)) + \underset{(0.003)}{0.010}dq_2 - \underset{(0.003)}{0.009}dq_3$$

$$+ (1 - \underset{(0.082)}{0.364} - \underset{(0.044)}{0.204})dP(-1)$$

Adjusted R^2 : 0.72 **D.W. = 2.41**

<u>6. The Lagged Inflation Expectations Equation</u>

$$Exp\_1 = \underset{(0.112)}{-0.623} - \underset{(0.008)}{0.025}d_{973aft} + \underset{(0.121)}{0.733}(FI(-1) + FI(-2))/200 + \underset{(0.030)}{0.246}dP(-1)*4$$

$$+ \underset{(0.83)}{0.083}d_{973aft}dE*4 + \underset{(0.089)}{0.504}AR(1)$$

Adjusted R^2 : 0.90 **D.W. = 2.08**

<u>7. The Nominal Wage Inflation Equation</u>

$$dW = \underset{(0.004)}{0.002} - \underset{(0.026)}{0.087}d951 + \underset{(0.067)}{0.762}dprod + \underset{(0.067)}{0.762}exp/4 + (1 - \underset{(0.067)}{0.762})dW(-4)$$

$$- \underset{(0.102)}{0.168}gap(-2) - \underset{(0.122)}{0.479}\ Ecw(-1)$$

Adjusted R^2 : 0.66 **D.W. = 2.05**

<u>8. The Labor Productivity Equation</u>

$$dprod = \underset{(0003}{-0.001} + \underset{(0.091)}{0.787}dW - 0.787dPgdp_{bs} - \underset{(0.083)}{0.248}dW(-4) + 0.248dPgdp_{bs}(-4)$$

$$+ (1 - 0.787 + 0.248)resdprod(-4)$$

Adjusted R^2 : 0.53 **D.W. = 2.49**

<u>9. The BoI Interest Rate Equation</u>

$$
\begin{aligned}
i_m = {} & \underset{(0.005)}{0.020} + \underset{(0.004)}{0.031}d_1 + \underset{(0.008)}{0.055}d_2 + \underset{(0.003)}{0.008}d_3 + \underset{(0.009)}{0.022}d_{91q4} - \underset{(0.006)}{0.018}d_{02q1} + \underset{(0.043)}{0.210}Exp \\
& + \underset{(0.069)}{0.548}d_{942aft}Exp + \underset{(0.052)}{0.223}d_{973aft}Exp - \underset{(0.086)}{0.473}d_{942aft}Target \\
& - \underset{(0.020)}{0.035}gap(-2) - \underset{(0.020)}{0.035}gap(-3) + \underset{(0.061)}{0.627}\, i_m(-1)
\end{aligned}
$$

Adjusted R^2 : 0.95 **D.W. = 2.22**

<u>10. The Debitory Interest Rate Equation</u>

$$
i_{hhd} = \underset{(0.004)}{0.093} - \underset{(0.003)}{0.049}d_{91aft} + \underset{(0.031)}{0.695}i_m + 0.305 i_{hhd}(-1) + \underset{(0.113)}{0.507}AR(1)
$$

Adjusted R^2 : 0.99 **D.W. = 2.01**